THE EFFECT OF EXPLICITLY DIRECTING ATTENTION TOWARD ITEM-FEATURE RELATIONSHIPS ON SOURCE MEMORY AND AGING: AN ERP STUDY

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THE EFFECT OF EXPLICITLY DIRECTING ATTENTION TOWARD ITEM-FEATURE RELATIONSHIPS ON SOURCE MEMORY AND AGING: AN ERP STUDY

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SUMMARY

Previous evidence has shown that older adults may have specific declines in prefrontal cortex (PFC)-mediated processes supported source memory retrieval, such as strategic retrieval and post-retrieval monitoring. This decline may manifest in the form of attenuated late-frontal ERP effects. Behavioral research suggests that explicitly integrating a target context, or source, with a stimulus during encoding will improve subsequent source memory performance for both younger and older adults. Explicit item-feature binding instructions during encoding may alleviate source memory impairments, in part, by reducing the need for strategic processing during episodic retrieval. The present ERP study investigated whether explicit direction of attention toward item-feature integration may reduce age-related deficits in source memory by alleviating the necessity of frontally-mediated strategic processing at retrieval. Results demonstrated that explicit direction of attention improved source memory accuracy for both young and older adults, but older adults benefited less than the young, indicating additional age-related deficits. ERPs revealed that explicit encoding support attenuated post-retrieval monitoring effects in the young. In the old, explicit encoding instruction resulted in earlier onset of early frontal effects, possibly related to familiarity. Results suggest explicit direction of attention toward item-source integration at encoding may improve source memory by alleviating the need for strategic retrieval, but age-related deficits persist.

CHAPTER 1

INTRODUCTION

Previous research has shown that recognition memory, or memory for previously encountered items, people, events, etc, may be supported by two dissociable processes. This dual-process model of episodic memory suggests that items may be remembered via *recollection* of specific contextual details of the initial experience, or via *familiarity* for the target in the absence of retrieval of contextual information (Mandler, 1980; Yonelinas, 2002). Several forms of experiments have been employed to investigate these memory processes. These experiments may be subjective in nature, or take more objective angles. One common objective method to assess recollection/familiarity is referred to as a "source memory" task. During the study portion of this task, participants are presented target stimuli (e.g. a word, an object, a spoken sentence, etc.), within experimentally manipulated contexts, i.e. the *source* for each item (e.g. a color, a semantic question, a location, etc.) and may either explicitly or implicitly encode the items and sources. At test, participants must both attempt to dissociate novel items from previously encountered items, as well as indicate which target context was associated with each previously encountered item (M.K. Johnson, Hashtroudi, & Lindsay, 1993). When a participant accurately retrieves the source, successful recollection has occurred. However, if the participant is able to correctly identify the object as previously seen, but is unable to correctly retrieve the source, they may have familiarity for the item, but no recollection of the source detail. It should be noted that failure to recollect the target source does not rule out recollection of non-criterial source details, i.e. other contextual details that were not associated with the experimental manipulation may provide a recollective experience (i.e. "non-criterial recollection"). Subjective measures, such as "Remember" judgments (Gardiner & Java, 1991; Tulving, 1985), by contrast, are less restrictive, in that participants may base their recollective response on any number of possible contextual details from the initial encoding episode. That said, it is difficult, if not impossible, to determine what the participant is specifically recollecting without specifically asking them.

There is a myriad of evidence suggesting that healthy aging, even in the absence of age-related neurodegenerative disorders, is associated with declines in recognition memory, generally attributed to declines in recollection (Spencer & Raz, 1995; Yonelinas, 2002). These declines are generally more prevalent in objective measures of recollection like source memory tasks than in subjective measures (Duarte, Henson, & Graham, 2008). In contrast, while there is evidence of age-related declines for subjective recollection, there is also evidence showing intact subjective recollection performance in older adults, even when recollection of specific source details may be impaired for the same stimuli (Duarte, et al., 2008; Duarte, Ranganath, Trujillo, & Knight, 2006; Mark & Rugg, 1998; Perfect, Williams, & Anderton-Brown, 1995). One suggestion is that these discrepancies may arise in part because objective measures of recollection rely more on strategic retrieval processing than subjective measures. Objective measures of recollection may heavily rely on processes such as elaboration and organization during initial encoding and monitoring and evaluation processes for retrieved information to successfully recollect the specific "source" at test. As a subjective measure allows a recollection judgment to be made based on any contextual detail, these processes may not be as necessary. Evidence suggests that these and other executive processes may be particularly disrupted by normal aging (Hasher & Zacks, 1979; M.K. Johnson, et al., 1993). Thus, it is possible that memory tasks placing high demands on these processes, such as typical source memory tasks where specific experimentally-manipulated details must be integrated during encoding and subsequently retrieved in the face of competing alternatives, may result in greater age-related discrepancies between younger and older adults.

Imaging research suggests that the prefrontal cortex, more specifically the dorsolateral PFC (DLPFC), contributes to these strategic processes at both encoding and retrieval. At encoding, the DLPFC is proposed to contribute to elaboration and organization of multiple contextual features, as well as facilitate associative encoding between these features (Blumenfeld & Ranganath, 2007 for review). During retrieval, the DLPFC may be involved in monitoring and evaluating retrieved episodic information, in the service of making a decision (e.g. "Is this item related to Source 1 or 2?") (Mitchell & Johnson, 2009 for review). These executive processes are believed to be engaged in a domain-general manner (i.e. regardless of the context/item type) (Smith & Jonides, 1999; Wagner, 1999).

Evidence from studies of younger adults has shown that the DLPFC may dissociate successful from unsuccessful source memory trials at both study (Cansino, Maquet, Dolan, & Rugg, 2002; Gottlieb, Uncapher, & Rugg, 2010) and test (Cansino, et al., 2002; Dobbins, Rice, Wagner, & Schacter, 2003) across multiple domains. Activity in the ventrolateral PFC (VLPFC) is often observed in source memory studies as well, but it is typically associated with successful encoding of item information, and not source information (Blumenfeld & Ranganath, 2007; Mitchell & Johnson, 2009). Taken together, these findings add to the idea that the DLPFC may be particularly involved in successful source memory, in a domain-general fashion via strategic processing.

Healthy aging disproportionately affects the lateral PFC, namely the DLPFC, both structurally and functionally (Buckner, 2004; Hedden & Gabrieli, 2005; Raz & Rodrigue, 2006; Van Petten et al., 2004). Such evidence is consistent with the "frontal aging hypothesis" (West, 1996), which suggests that the frontal regions of the brain are the earliest and most greatly affected regions of age-related decline. Thus, memory tasks that are particularly dependent on DLPFC might be disproportionately affected by aging, such as the source memory tasks discussed previously. Consistent with this implication, event-related fMRI research has shown DLPFC activity to be associated with source recollection (i.e. successful vs. unsuccessful source) at test, and that this activity may disrupted in older adults, consistent with their behavioral impairments in spatial and temporal source memory accuracy (Duarte, et al., 2008; Rajah, Languay, & Valiquette, 2009). Consistent with these findings, other studies suggest that age-related alterations in DLPFC source recollection activity at study (Dennis et al., 2008) and test (Rajah, et al., 2009), may contribute to age-related deficits in recollection during objective source memory tasks, for face-scene pairings and temporal/spatial contexts, respectively. Taken together, these findings, as well as patient evidence showing that damage to this region produces marked source memory impairments (Duarte, Ranganath, & Knight, 2005; Janowsky, Shimamura, & Squire, 1989; Swick, Senkfor, & Van Petten, 2006), suggest that age-related structural and functional alterations in the DLPFC are likely contributors to source memory deficits in healthy older adults for various types of materials and contexts.

The question then becomes: do these age-related alterations in the DLPFC and strategic processing cause ubiquitous deficits in source memory tasks, or are there methods by which a person may be able to behaviorally compensate for these deficiencies? There is some behavioral evidence which shows that explicit encoding instructions can facilitate the association between an item and its target context (source), and can eliminate source memory deficits in older adults. For instance, if a participant is directed to specifically attend to the relationship between an item and its experimentally-manipulated association during study (e.g. "How well does this chair (item) fit the room (source)?"), age-related source memory impairments are reduced (Glisky & Kong, 2008; Glisky, Rubin, & Davidson, 2001; Hashtroudi, Johnson, Vnek, & Ferguson, 1994; Naveh-Benjamin, Brav, & Levy, 2007). In such cases, participants must directly *integrate* the item and the source at encoding. It is further suggested that the PFC is necessary for allocating attention to both the item and its context, as well as for facilitating the binding between the two (Glisky & Kong, 2008; Glisky, et al., 2001); a process which, as previously suggested, is likely dependent on the DLPFC. The inference of this is that older adults with reduced DLPFC functioning may fail to spontaneously initiate appropriate encoding strategies, which would enable them to bind items and their associations more effectively. However, when encoding is supported by explicit integrative binding instructions, they should be better able to retrieve the correct source in the face of competing alternatives.

Environmental support, as via explicit item-source binding instructions during encoding, may further reduce source memory deficits in older adults, in part, by affecting retrieval processing. That is, items and contexts that are weakly bound at encoding may disproportionately rely upon strategic retrieval processes at test, while items and contexts that are strongly bound at study may be more easily retrieved at test. Behavioral studies alone are insufficient to separate the contributions of encoding and retrieval to source memory, or to determine whether aging affects either or both stages. However, a recent event-related potential (ERP) study suggests that explicit item-feature encoding instructions can reduce frontally-distributed source retrieval ERPs at test, compared to instructions that were focused solely on the item (Kuo & Van Petten, 2006). These results suggest, when associations are tightly bound during encoding, PFC involvement during retrieval may be reduced. However, it is difficult to determine from ERPs alone what particular brain regions are involved in specific processes. Nevertheless these data, taken together with the evidence discussed previously, which show that DLPFC activity contributes to source memory retrieval via evaluation and monitoring, suggest that the DLPFC may be more greatly involved when episodic attributes are weakly bound during initial encoding and thus required for strategic processing. Given that older adults exhibit impairments to DLPFC-mediated processes, age-related source memory deficits may be more pronounced when strategic retrieval processing is necessary, such as when attributes are weakly bound in memory. If an item and associated contextual details are more tightly bound during encoding, recollection may occur without a great deal of dependence on strategic retrieval processing. Further, it is likely that it takes additional processing time to recover a more weakly encoded item-context association, which likely necessitates additional evaluation and monitoring before a decision can be made. ERPs provide excellent temporal resolution about the time courses of processes. Some ERP evidence has shown widely distributed early onsetting (~200 ms post retrieval cue) differences between studied and unstudied objects during source retrieval, regardless of whether the object-source (color) relationship was explicitly attended to during study (Kuo & Van Petten, 2006). However, later onsetting (~700 ms post retrieval cue) frontally-distributed ERP differences between studied and unstudied objects, observed in other source memory retrieval studies (M. D. Rugg & Curran, 2007; Wilding, 1999), were only observed when the association was weakly encoded, i.e. not explicitly integrated at encoding. Because of the time course of this frontal ERP effect, namely its later latency, it has been argued that it may reflect secondary searches for episodic associations, particularly when these associations are difficult to recover initially after the item has been recognized (Senkfor & Van Petten, 1998). However, the exact nature of how this effect is modulated is unclear. There is some evidence suggesting the magnitude of this late-frontal effect may be modulated by the number of internal decisions being carried out during test, while other evidence suggests this effect may be modulated by confidence (Cruse & Wilding, 2009).

Regardless of its underlying mechanisms, there is evidence to suggest that these late frontal ERPs are often reduced in magnitude and temporally delayed in older adults, as shown in typical source retrieval studies of aging (Gutchess, Ieuji, & Federmeier, 2007; Trott, Friedman, Ritter, & Fabiani, 1997; Wegesin, Friedman, Varughese, & Stern, 2002). This may be related to the age-related changes in frontal lobe function mentioned earlier. If there are impairments in older adults' ability to engage in post-retrieval monitoring, explicit item-feature binding instructions at encoding may ameliorate these age-related declines in source memory performance by lessening the need for frontally-mediated strategic retrieval processing at test. As a lower amount of PFC-mediated strategic retrieval processing may be necessary at retrieval when facilitated by explicit integrative encoding instruction, and older adults may already have attenuated strategic retrieval processing ERPs, these effects may more similar between groups (Blumenfeld & Ranganath, 2007).

The present study sought to investigate the effect of explicit direction of attention to item-feature conjunctions on source memory accuracy, as well as its effect on age-related changes in source memory performance and related ERPs. An event-related potential EEG design was employed to investigate the neural patterns of activity associated with source recollection after explicit and non-explicit direction of attention encoding conditions. Specifically, during study, participants saw colored objects presented with one of two encoding tasks; one which specifically required the participant to attend to/integrate the object and its color, and another that was item-oriented, with no explicit direction regarding the color. At test, participants saw studied and unstudied objects, half of which were presented in a different color than during encoding. Participants first judged whether they had seen each object or not, regardless of its current color. Additionally, they then determined if old items were presented in the same color as during encoding, or if they were presented in a different color. Lastly, the memory load was adjusted between young and older adults in an attempt match participants on performance. It has been suggested this may allow for investigation of true aging differences, as opposed to differences in performance (e.g. Morcom, Li, & Rugg, 2007).

Based on these considerations, we predicted the following:

1) For both younger and older adults, source memory would be significantly more

accurate for the explicit encoding task condition than for the non-explicit condition. Explicit direction of attention towards the integration of item and source should facilitate the binding of items and features at encoding and allow for improved recollection at retrieval.

2) Even with our attempt at matching performance, we still predicted that older adults might show age-related declines in source memory, but that these declines would be ameliorated when objects and their associated colors were explicitly bound. This may result in one of two outcomes: either the older adults may be nearly as accurate as younger adults in the explicit condition, but not the non-explicit; or older adults may show an overall decline in source memory, but still retain improved source memory under explicit item-feature binding instruction conditions than under indirect instruction conditions, i.e. a main effect of age and a main effect of condition, but no interaction between age and condition.

3) With reference to ERP results, as older adults have been shown to have attenuated frontal ERP source retrieval effects, we predicted that older adults would show reduced old-new ERPs for both conditions compared to the young. Additionally, as older adults have been shown to exhibit cognitive slowing, particularly for cognitively demanding operations like source memory tasks (Salthouse, 2000), older adults may show general age-related slowing in ERP latency at retrieval, but this may be less severe for the explicit condition. That is, dissociations in ERP latencies between successful and unsuccessful source memory for explicit trials may occur sooner than those for non-explicit trials for both groups.

4) Additionally, we predicted that ERPs for successful compared to unsuccessful

source trials should display a sustained latency (> ~700 ms) for retrieval of weakly bound associations, reflecting increased PFC-mediated strategic retrieval processing. We also predict larger age-related differences in ERP magnitude during retrieval of items not encoded under the explicit direction of attention instructions, as item-source conjunctions in the non-explicit condition may require increased frontally-dependent strategic retrieval processes, which are suggested to be disproportionately affected by aging. Further, if accuracy is more similar between groups for the Explicit condition, it is possible ERP magnitude would be more similar between groups as well (Li, Morcom, & Rugg, 2004).

CHAPTER 2

METHODS

2.1: Participants

18 young adults (YAs), ages 19-33 (10 F, 8M; mean age: 24 yoa, edu: 16.5 years) were recruited from Georgia Institute of Technology, as well as community solicitation, and 18 older adults (OAs), ages 60-79 (8F, 10M; mean age: 66 yoa, edu: 16.5 years), were recruited via community solicitation. All participants were right-handed, native English speakers, with normal or corrected to normal vision, with no reports of psychiatric/neurological disorders, vascular disease, or psychoactive drug use. None of the participants were taking CNS-active medications or anti-hypertensive medications**.** All participants were paid $10 an hour for their time and sign consent forms approved by the Georgia Institute of Technology Institutional Review Board. Young adults (YAs) and older adults (OAs) did not significantly differ in gender proportion or level of education.

2.2: Neuropsychological Assessment

All participants were administered a battery of standardized neuropsychological tests after completing the EEG portion of the experiment. Tests were specifically chosen to assess memory ability and executive functioning, so as to ensure no gross differences in performance due to cognitive impairment such as dementia in the older group. The battery included subtests from the Memory Assessment Scale battery (Williams, 1991): digit span forward and backward, list learning, recognition, recall and delayed recall, object recognition, recall, reproduction, and delayed recognition. Additionally, the Trail making tests, A and B (Reitan & Wolfson, 1985), as well as the Controlled Oral Word Association Test (“FAS”) (Benton, Hamsher, & Sivan, 1983), and a computerized version of the Wisconsin Card Sorting Task (Psychological Assessment Resources. Computerized Wisconsin Card Sort Task Version 4 (WCST). Psychological Assessment Resources; 2003) were included. All included participants scored within a standard deviation of age-related norms on these tests.

2.3: Materials

360 color images were used as stimuli. All images depicted a single, nameable object on a white background. Images were mostly taken from the Hemera Technologies Photo-Objects DVDs, though several images found online via Google were included as well. There was no overlap of multiple images depicting the same object. Each object was adjusted via Adobe Photoshop so that they were standardized to a specific shade of one of four possible colors: red, green, blue, or brown.

2.4: Design

The paradigm is shown in **Figure 1**. The experiment was divided into two parts, study and test. Young adults conducted four blocks for study, followed by four blocks of test. For older adults, the memory load was split in half, so that they performed two blocks of study, followed by the corresponding two blocks of test, and then completed the remaining two blocks of study and their corresponding blocks of test. Delays were imposed between study and test phases for both groups during which participants performed a short vocabulary test. For younger adults, this test lasted 10 minutes. For older adults, this test was divided evenly between the two Study-Test sessions, such that there was a 5 minute vocabulary test in between study and test blocks. Immediately

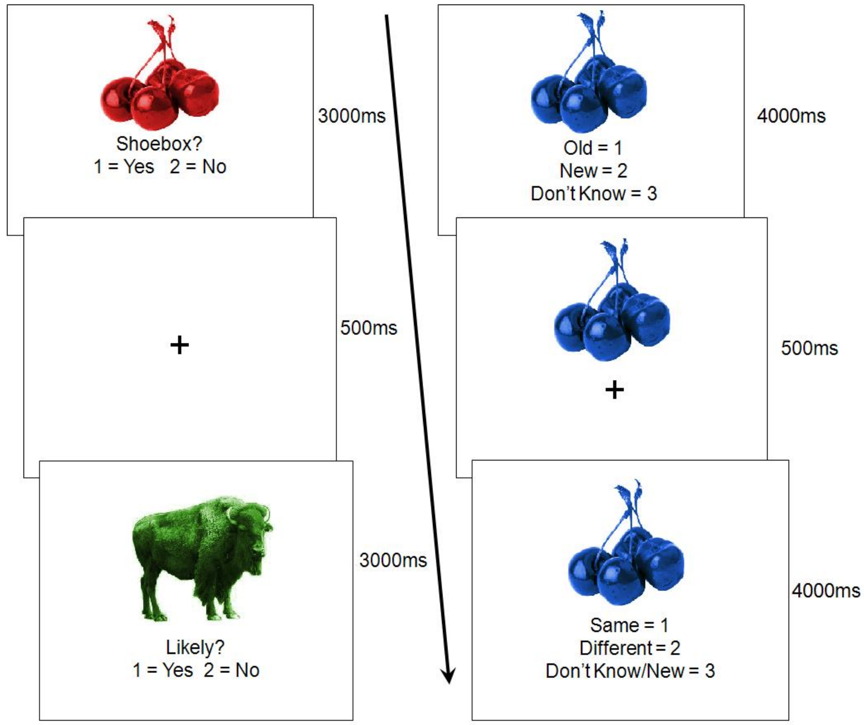

Figure 1. Experimental Design.

before the experiment, participants completed a short practice of both study and test trials. The experiment was presented using EPrime 1.0 on a Dell desktop computer. All responses were made with the right hand, using an external num pad, using buttons 1, 2, and 3, with index, middle and ring finger pressing each respectively. Each study block consisted of 60 trials, during which participants were presented with colorized objects accompanied by a yes/no question. There were two possible questions, each of which appeared on 50% of the encoding trials. Participants either answered the question "Is this color likely for this object?" (Explicit Condition) or "Is this object bigger than a shoebox?" (Non-Explicit Condition). Participants were instructed that these questions may be treated as subjective and to simply answer as they saw fit. That is, participants were told that there may be no distinctly "correct" answers to the two encoding questions for some trials. For example, some participants may have a bluish metal spoon at home, and consider a blue spoon likely; while others may not have the same experience and consider it unlikely. Further, for the “Shoebox?” question, some objects, like a sweater, may fit into a shoebox if folded up, but not if laid out upon a table. However, as best as possible, 50% of the items are a color that should elicit a “Yes” to the “Likely?” question, and 50% of them should elicit a “No.” This is also true for the “Shoebox?” question. That is, though these questions may be answered subjectively, each object had a “more probable” response (e.g. a red fire truck is more likely to be called “Likely”). Additionally, each study block was further divided into 4 mini-blocks of 15 questions, with each mini-block introduced by a 7-second cue indicating which question would now be answered. This was done to alleviate task-switching demands that would be necessary with a pseudorandomized presentation order on a trial-to-trial basis. All subjects responded with button 1 for “Yes” and button 2 for “No.” Each trial lasted 3000 ms in duration with a jittered (400, 500, or 600 ms) fixation cross appearing between trials.

During the test phase, each of the four blocks consisted of 90 trials, 60 of which were old items, and 30 new, so that there were half as many new items as old items total. Each block had an equal number of words encoded under the Explicit (Likely?) and Non-Explicit (Shoebox?) conditions. Further, 50% of all old items at test remained the same color as at Study, while 50% changed to an alternate color (i.e. if the item was blue originally, it could be red, green, or brown if changed). All objects were pseudorandomized across the 4 test blocks, and test block order was pseudorandomly varied across participants. Each trial at test consisted of an “Old – New – Don’t Know” question, presented for 3000 milliseconds, a 500ms fixation cross, followed by a “Same –

Different – Don't Know" question, followed by a jittered (400, 500, or 600 ms) trial break showing a fixation cross. Thus, for each item, participants answered 2 questions. For the first question, participants answered whether the object was Old or New, by pressing button 1 for "Old," button 2 for "New," and button 3 for "Don't Know", where the last option indicated that the participant was not sure whether the item was old (studied) or new (unstudied). Regardless of their response, they were then be asked if the color of the object was the same or different from encoding. Button 1 corresponded to "Same," button 2 to "Different," and button 3 to "Don't Know/New," with the last option should indicating that the participant was not sure whether the object was presented in the same or a different color as during study. Participants responded with their right hand. For both retrieval decisions, the "Don't Know" response was provided to reduce potential contamination by guesses in both item and source memory accuracy and ERPs.

2.5: ERP Acquisition

Scalp-recorded EEG data was collected from 32 Ag-AgCl electrodes using an ActiveTwo amplifier system (BioSemi, Amsterdam, Netherlands). Electrodes were positioned according to the extended 10–20 system (Nuwer et al., 1998). Electrode positions included AF3, AF4, FC1, FC2, FC5, FC6, FP1, FP2, F7, F3, Fz, F4, F8, C3, Cz, C4, CP1, CP2, CP5, CP6, P7, PO3, PO4, P3, Pz, P4, P8, T7, T8, O1, Oz, and O2. Two electrodes were placed on the left and right mastoids to act as the reference electrodes. Four additional leads were placed above and below the left eye and on the outer canthi of the left and right eyes. These leads were used to form vertical electrooculogram (VEOG) and horizontal electrooculogram (HEOG), respectively. The ActiveTwo system replaces traditional reference and ground electrodes with common mode sense (CMS) and driven right leg (DRL) electrodes. EEG from all channels was acquired with respect to the CMS electrode and digitized at 1024 Hz.

Data was collected for both study and test phases of the experiment. For the purposes of this manuscript, EEG data from Test will be primarily addressed. Off-line, data was re-referenced to mastoid electrodes and digitally band-pass filtered between 40 Hz and 0.01 Hz. Data was then polynomial detrended across the whole time line, to correct for drift in the EEG across recording sessions. Epochs containing amplifier saturating artifacts (±100 μV) that occurred between 200ms prestimulus to 1400ms poststimulus were excluded prior to averaging. Epochs with correctable eye movements were corrected by a method based on principal component analysis, as is available in EMSE version 5.3 (Pflieger, 2001). EEG segments were formed from an interval 200 ms prior to stimulus onset to1400 ms after stimulus onset.

2.6: Behavioral Analysis

Each studied object had five possible responses: Source Correct (SC: responded old with correct source), Source Incorrect (SINC: responded old but with incorrect source), Don't Know (SDK: responded old but don't know which source), Don't Know:Old/New (responded Don't Know to old/new question), and Miss (responded new). Each new object can be classified as either: Correct Rejection (CR: respond new), False Alarm (FA: respond with one of the three old judgments) or Don't Know:Old/New. Mixed-design, repeated measures ANOVAs were used to compare accuracy estimates within and between groups for item memory (Hits – False Alarms) and source memory (SC/ [SC + SINC] – SINC/ [SC + SINC]) so that chance was set at 0.0 for both measures.

Mixed-design, repeated measures ANOVAs were also employed to compare response times (RTs) between conditions and groups.

2.7: ERP Analysis

ERPs to objects were averaged based on the subject's behavioral response at test, separately for each encoding condition (Explicit Condition, Non-Explicit Condition). That is, ERPs were averaged separately for items that elicited correct source memory judgments (SC), and compared to ERPs averaged for correctly rejected new items (CR). We intended to analyze averages for incorrect source memory judgments (Source Incorrect) and "Don't Know" source judgments (Source Don't Know), but there was an insufficient number of participants in each group with enough of these trials to successfully look at this condition, even when SINC with SDK trials were combined. Similarly, there were insufficient numbers of old items misidentified as new (Miss), or new items identified as old (False Alarms) to analyze.

Mean ERP amplitudes were computed for each condition at left and right electrode sites and analyzed by region, i.e. frontal, frontal-central, central, etc. sites. Within group ANOVAs were employed for each condition, including factors of Electrode Location, Hemisphere, and Response (SC vs. CR). Time windows were selected based on previous results from our lab and similar ERP studies (e.g. Cruse & Wilding, 2009). Where appropriate, reported *P*-values were corrected using Huynh-Feldt corrections. Significant main effects and interactions at an alpha (α) level of 0.05 were followed up with *t*-tests to determine the source of the effects.

In order to limit the number of analyses, data were selected from 14 electrodes (AF3/4, C3/4, F3/4, F7/8, FC5/6, FP1/2, P3/4), in correspondence with our previous studies (Dulas, Newsome, & Duarte, 2011), with a heavier focus on frontal electrodes given our specific interest in frontal effects. Data from selected electrodes were subjected to within-group ANOVAs for each age group separately in order to investigate possible differences in onset of source memory effects between conditions, with factors of condition [Source Correct, Correct Rejection], electrode location, and hemisphere. In order to assess source memory effects, namely the late onsetting frontal maximal retrieval monitoring effects discussed earlier, 4 time windows were chosen (200-500ms, 500-800ms, 800-1100ms, and 1100-1400ms), consistent with previous studies (e.g. Cruse & Wilding, 2009). The main goal of these analyses was to determine if the two encoding task conditions showed differences in magnitude of activity within latency windows in which there were reliable effects. To this end, where appropriate (i.e. significant old-new effects in both conditions within the same window) raw difference scores of the old-new effects were subjected to within-group, between condition ANOVAs, with factors of condition [Explicit Condition, Non-Explicit Condition] , electrode location, and hemisphere. Lastly, in order to determine if any topographical differences are present in any latency window between conditions, difference wave scores were rescaled by the vector length method (McCarthy & Wood, 1985; Ruchkin, Johnson, & Friedman, 1999) and subjected to ANOVAs of location, condition, and hemisphere.

Between-group analyses were also performed where appropriate in order to directly compare ERP effects between age groups. First, the raw difference scores for each condition were subjected to ANOVAs that included factors of group, hemisphere, and location, in order to investigate group differences in effect magnitudes, which would signify different levels of activity strength. Additionally, ANOVAs were performed on the vector length rescaled difference score values in order to investigate condition and group differences in scalp topographies for each effect, which would signify possible differences in neural generators (M.D. Rugg, 1995).

CHAPTER 3

RESULTS

3.1: Behavioral Results

Item recognition accuracy was estimated by the Pr measure of discriminability, i.e. p(hits) – p(false alarms) for Explicit and Non-Explicit encoding conditions. Young adults showed item memory accuracy of 81.1% and 80.6% for the Explicit and Non-Explicit items, respectively. Older adults, showed item memory accuracy of 78.9% and 74.4% for Explicit and Non-Explicit items, respectively. Source accuracy was also estimated by Pr, excluding "don't knows", i.e., Pr = p(correct) – p(incorrect). Source memory estimates for young adults were 68.3% and 30.0% for the Explicit and Non-Explicit conditions, respectively. For older adults, these estimates were 54.0% and 30.9%. These item and source accuracy estimates for young and older adults are shown in **Figure 2**. As noted previously, memory load was halved for older adults as an attempt to match memory performance on the tasks.

To assess the effects of explicit direction of attention at encoding on item memory accuracy we conducted a Condition (Explicit, Non-Explicit) x Group (young, old) ANOVA on the Pr measures. The ANOVA revealed a reliable main effect of Condition [$F(1,34) = 11.20$, $p = 0.0002$], which was modified by Condition x Group interaction [$F(1, 34) = 7.04$, $p = 0.01$]. The main effect of group was not significant [$F(1,34) = 1.05$, $p = 0.31$]. Subsidiary analyses revealed that this interaction reflected a main effect of condition that was reliable for OAs [$t(17) = 3.82$, $p = 0.001$] but not YAs [$t(17) < 1$].

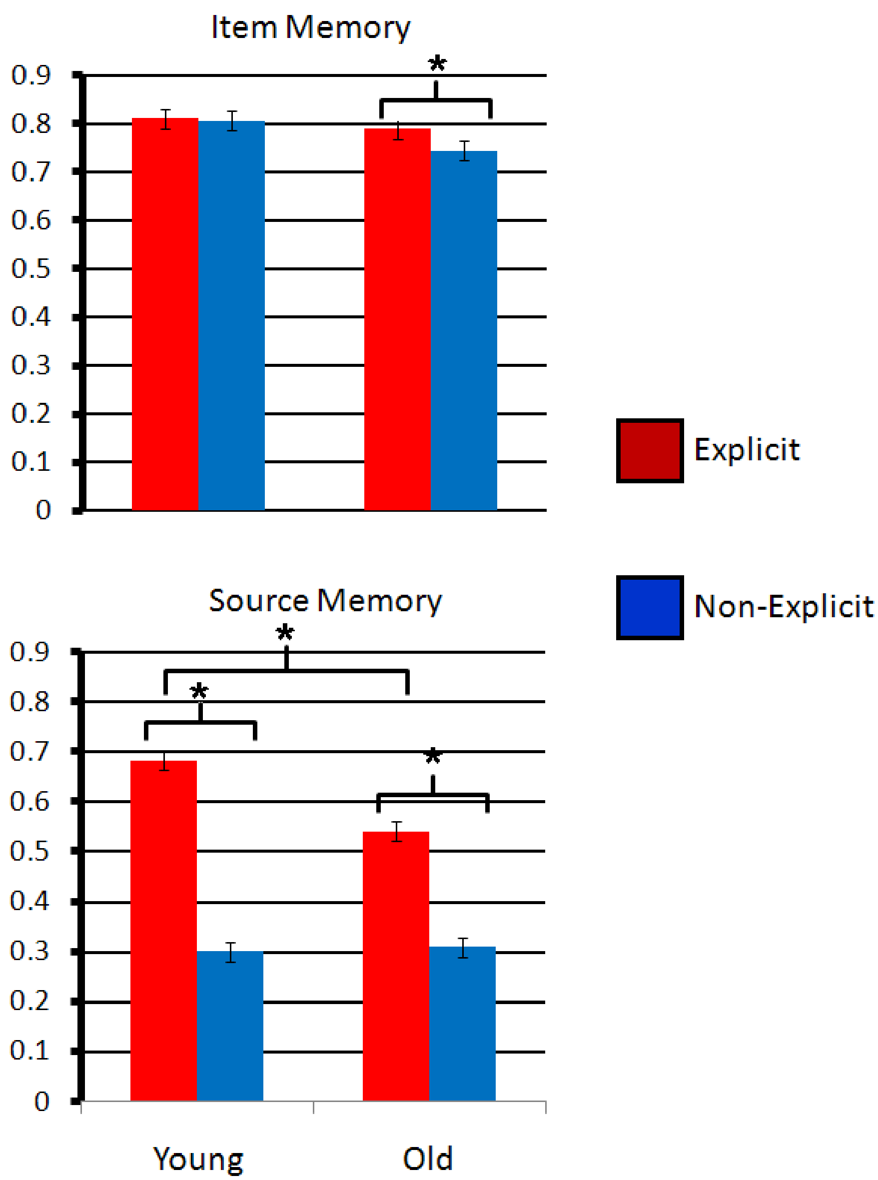

Figure 2. Behavioral Results

However, there were no significant differences between the two groups for either condition [t(34)'s 1.38, $p > 0.17$]. Thus, the memory load manipulation successfully matched young and older adults on item memory.

The ANOVA for source memory accuracy revealed a main effect of Condition [F(1,32) = 145.61, $p < 0.001$], modified by a Group x Condition interaction [F(1,32) =

8.92, $p = 0.005$]. Subsidiary analyses revealed that both groups benefitted from explicit direction of attention at encoding [$t(17)$'s > 7.13, p's < 0.001], but young adults had better source memory accuracy than the old for the Explicit condition [$t(34) = 2.12$, $p = 0.04$], though not the Non-Explicit [$t < 1$]. Thus, as can be seen in **Figure 2**, the groups were matched on item memory accuracy and source memory accuracy after non-explicit direction of attention. Further, while both groups received a benefit from Explicit direction of attention, older adults did not receive the same magnitude of benefit as young adults.

Mean reaction times (RTs) for correct memory judgments in YAs were 1243.83ms for Explicit and 1238.22ms for the Non-Explicit condition, while their mean for Correct Rejections was 1369.33ms. For OAs, these values were 1548.33ms, 1542.50ms & 1623.61ms respectively. A Response (Explicit source correct, Non-Explicit source correct, CR) x Group (young, old) ANOVA was performed, revealing main effects of Response [$F(2,68) = 13.20$, $p < 0.001$], and Group [$F(1,34) = 20.32$, $p < 0.001$]. These effects reflect that young adults were faster across all responses than older adults, but, for both groups, CR's were slower than the source correct responses.

3.2: ERP Results

ERPs to items studied in the Explicit and Non-Explicit encoding conditions and associated with correct source judgments and ERPs for correctly rejected new items are shown for selected electrode sites for the young in **Figure 3** and the older adults in **Figure 4**. For both groups, widespread old-new effects similar to those reported in previous studies (see Introduction) were observed with correct source ERPs for each task eliciting more positive-going activity than correct rejection ERPs beginning at roughly 200 ms post-stimulus.

3.3: Old-New Effects

3.3.1: 200-500 ms

Young Adults: For each window, a within condition Location (Anterior Frontal, Central, Frontal Medial, Frontal Lateral, Frontal Central, Frontopolar, and Parietal) x Hemisphere x Condition (SC, CR) ANOVA was conducted. For the Explicit condition, this analysis showed a marginal main effect of Condition [$F(1,17) = 3.11$, $p = 0.09$], which was revealed to be reliable at left-lateralized parietal, anterior-frontal, and medial-frontal locations. As for the Non-Explicit condition, the ANOVA revealed a significant main effect of Condition [$F(1,17) = 8.83$, $p = 0.01$], reflecting a widespread distribution that was significant at all electrodes, though only marginally so at frontopolar locations.

Older Adults: Within this early time window, for the Explicit condition, older adults showed a main effect of Condition [$F(1,17) = 4.72$, $p = 0.04$], which was modified by a Location x Condition interaction [$F(6,102) = 2.35$, $p = 0.05$]. This reflected a pattern of activity that was reliable at all locations other than central and parietal (i.e. all frontal locations). For the Non-Explicit condition, the ANOVA revealed no significant effects or interactions.

Summary of 200-500 ms time window: Results showed that old-new effects were already present for young adults in both conditions, though these were much more widespread for the Non-Explicit condition. As for older adults, while they showed frontal old-new effects for the Explicit condition, the old-new effects for the Non-Explicit condition had not yet reached significance.

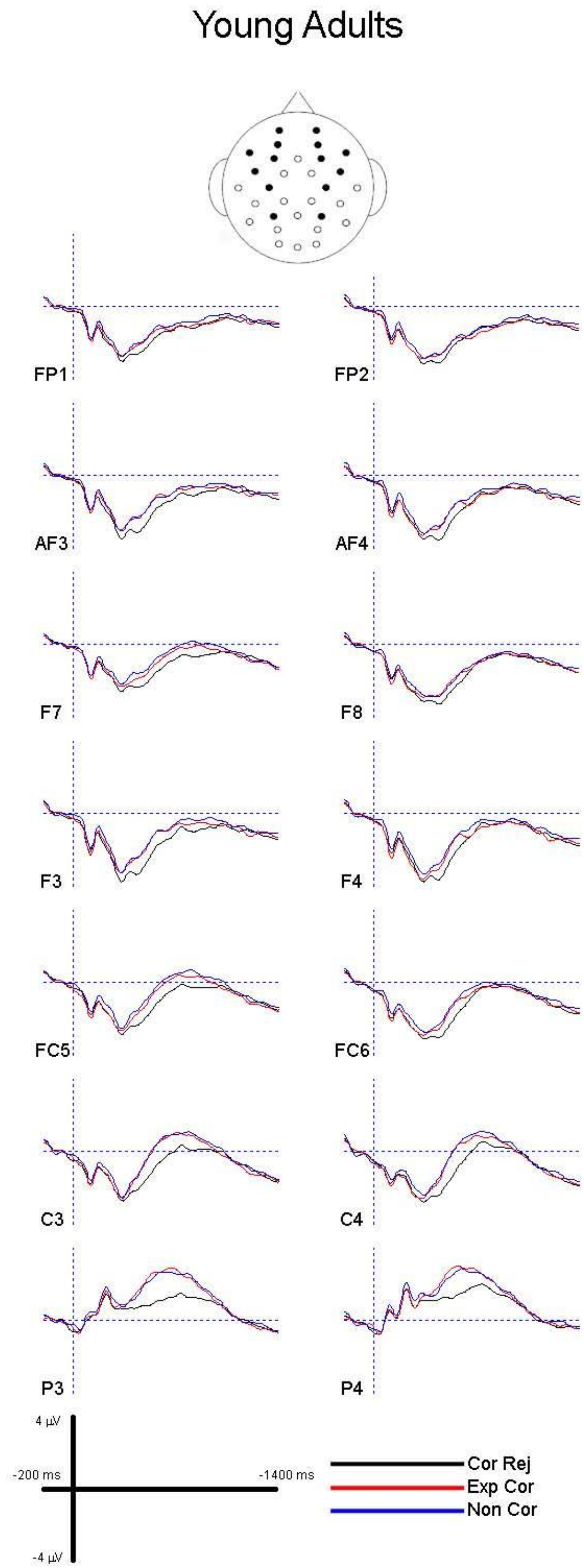

Figure 3. ERPs for Young Adults

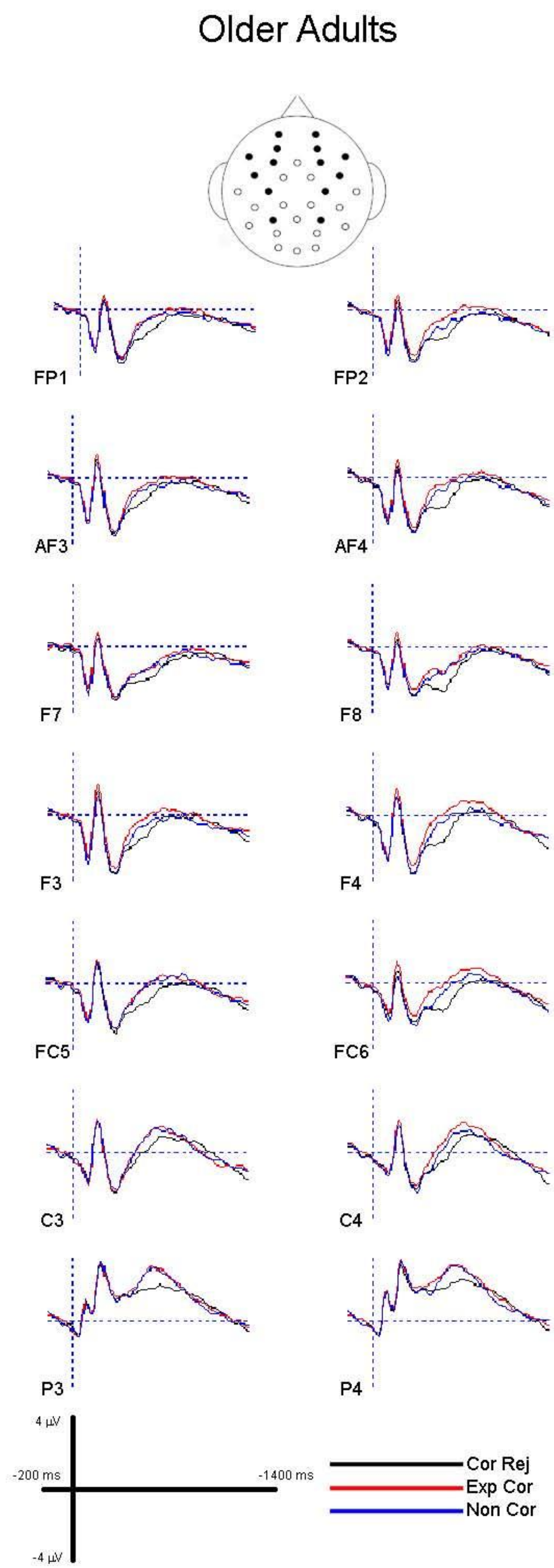

Figure 4. ERPs for Older Adults

3.3.2: 500-800 ms

Young Adults: In the 500-800 ms window, for the Explicit condition, young adults showed a main effect of Condition [$F(1,17) = 5.51$, $p = 0.03$] which also interacted with Location and Hemisphere [F's > 6.35, p's < 0.03]. This reflected a pattern of old-new effects that were significant at central, parietal and frontal central locations, as well as marginally reliable at left-lateralized anterior frontal and medial frontal locations. The main effect of condition was also significant for the Non-Explicit condition in YAs [$F(1,17) = 5.01$, $p = 0.04$] as well as a significant interaction with location [$F(6,102) = 7.90$, $p = 0.01$] and a marginal interaction with hemisphere [$F(1,17) = 3.70$, $p = 0.07$]. Subsidiary analyses revealed reliable old-new effects at central, parietal, and left lateralized frontal central and medial central locations.

Older Adults: For the Explicit condition, older adults showed a main effect of Condition in this window [$F(1,17) = 13.09$, $p = 0.002$] which was modified by a Hemisphere x Condition interaction [$F(1,17) = 7.09$, $p = 0.02$], reflecting that, although the old-new effects were reliable at all electrodes, the effects were stronger in the right hemisphere. As for the Non-Explicit condition, there was a main effect of Condition [$F(1,17) = 4.86$, $p = 0.04$], but no significant interactions.

Summary of 500-800 ms time window: In both groups, old-new effects have become reliable and widespread across conditions. Interestingly, there appear to be age differences in the lateralization of these effects under Explicit direction of attention, as YAs show stronger effects in the left hemisphere while OAs show stronger effects in the right.

3.3.3: 800-1100 ms

Young Adults: In this time window, for the Explicit condition, young adults showed a Hemisphere X Condition interaction [$F(1,17) = 10.42$, $p = 0.005$]. However, subsidiary analyses revealed that there were no reliable old-new effects at any electrode location. The Non-Explicit condition also showed a significant Hemisphere X Condition interaction [$F(1,17) = 15.69$, $p = 0.001$]. Subsidiary analyses revealed these effects were reliable at left-lateralized lateral frontal and frontal central locations.

Older Adults: Within this window, there were Hemisphere x Condition interactions for both the Explicit [$F(6,102) = 2.75$, $p = 0.04$] and the Non-Explicit conditions [$F(6,102) = 2.08$, $p < 0.1$]. However, subsidiary analyses show now reliable effects at any electrodes within this time window for either condition.

Summary of 800-1100 ms time window: The old-new effects in the older adults ceased being reliable, as did the effects for the Explicit condition in the young adults. The Non-Explicit condition for the young adults however still is show sustained frontal effects, albeit left lateralized.

3.3.4: 1100-1400 ms

Young Adults: The Explicit condition showed no reliable effects or interactions in this time window. The Non-Explicit condition show a marginal Hemisphere X Condition effect [$F(1,17) = 4.21$, $p = 0.06$], which was revealed to be reliable in right-lateralized medial frontal, frontal central, and frontopolar locations.

Older Adults: Neither condition showed reliable effects or interactions in this time window.

Summary of 1100-1400 ms time window: Old-new effects are not apparent for older adults for either condition, or for young adults in the Explicit condition. Young adults however did show right lateralized frontal effects in this time window for the Non-Explicit condition.

3.4: Raw Difference Wave and Topographical Analyses

Topographical maps for windows and conditions showing significant old-new effects are shown in **Figure 5**.

As suggested previously, it is only appropriate to run between condition/group analyses for time windows in which both conditions/groups have reliable effects, so as not to bias results toward finding effects (e.g. if there is an effect in one group but not in the other, then there clearly would be a difference in these analyses). Given this, for between condition analyses, only the 200-500 ms and 500-800 ms time windows can be looked at for the young, and only 500-800 ms for the old, as the remaining windows have at least one condition with no reliable effect. One additional within group analysis is to compare the topography of the late frontal effects between the 800-1100 and 1100-1400 ms windows for the Non-Explicit condition. Lastly, between groups comparisons can only be done for the 200-500 ms window for Explicit and the 500-800 for both conditions.

3.4.1: Between Conditions

There were no differences between conditions in magnitude or topography in the 200-500 ms window for the young adults, nor for the 500-800 ms for the young or the old. This suggests that these earlier effects do not differ in magnitude or topography between conditions.

3.4.2: Between Windows

To examine whether the 800-1100 old-new effects were continuing into the 1100-

1400 ms window or if they were distinct late frontal effects, we employed a Location X Hemisphere x Window ANOVA with the vector length scaled data. The ANOVA

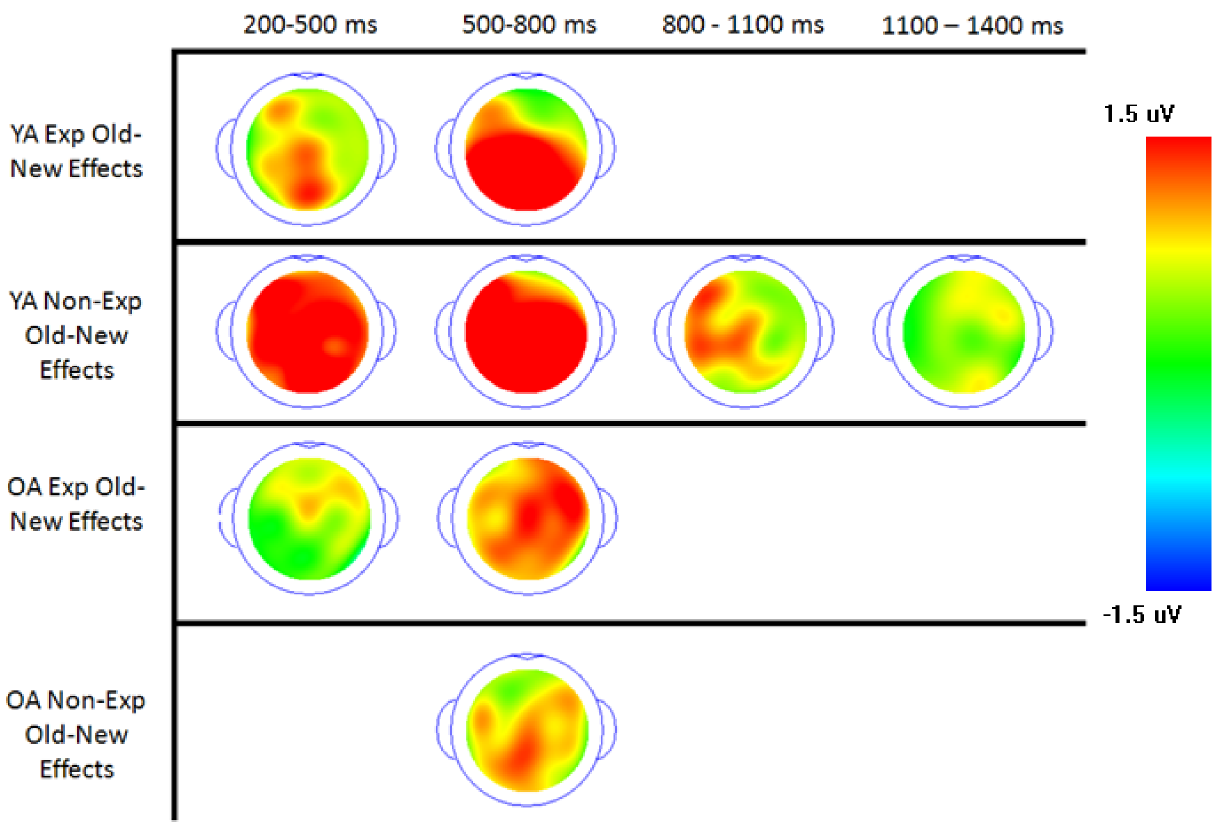

Figure 5. Topographic Maps

revealed a significant Hemisphere X Window effect, reflecting that the effects in the 800-1100 ms window were left lateralized and the effects in the 1100-1400 ms window were right lateralized. This suggests that these are perhaps two distinct late frontal effects.

3.4.3: Between Groups

The only window that warranted further analysis was the 500-800 ms window, as all others contained conditions with no reliable old-new effects. However, there were no Group x Condition interactions for raw or vector length rescaled difference wave analyses. This suggests that these effects in the 500-800 ms time window are similar between groups.

CHAPTER 4

DISCUSSION

The current study investigated explicit direction of attention at encoding toward item-feature integration and its effect on age-related impairments in source memory. As predicted, explicit direction of attention toward the conjunction of item and feature improved source memory accuracy for the feature in both young and older adults. Interestingly however, despite being matched on performance for item memory and source memory in the non-explicit condition, older adults did not get the same magnitude of performance boost from explicit encoding instruction. ERP results showed that, as in previous studies, explicit direction of attention toward item-feature binding attenuated late-frontal post retrieval monitoring effects in young adults. Further, in the Non-Explicit condition, young adults showed two distinct post-retrieval monitoring effects, suggesting that post-retrieval monitoring may involve multiple mechanisms and neural generators. Older adults showed no evidence of post retrieval effects for either condition, but results showed that, in the Explicit condition, older adults may look more like young adults with regards to ERPs. That is, while older adults showed a delay in the onset of old-new effects under the Non-Explicit condition, the Explicit condition show old-new effects coming online within the same window as for young adults. These results and their implications are discussed further below.

4.1: Behavioral Results

As predicted, explicit direction of attention at encoding did improve source memory accuracy for younger and older adults, and may have improved item memory accuracy in older adults as well. These effects were present for source memory even when item memory was equal between conditions, suggesting that the mediation of strategic retrieval processes via explicit direction of attention at encoding was more critical for source memory versus item memory. That is, item memory may not require a great deal of strategic processing at retrieval, and thus remained relatively unaffected by the encoding manipulation. However, while the older adults did display a benefit to source memory accuracy from the Explicit encoding condition, the magnitude of this benefit was significantly less than for young adults, even when both groups were matched on performance for item memory, as well as source memory in the Non-Explicit condition. Thus, explicit integrative encoding instructions alone did not completely raise older adults' accuracy to the level of the young, as some previous research has suggested it may (Glisky, et al., 2001).

There are a few possible explanations for these behavioral results. One possibility is that this is a product of our memory load manipulation. It is possible that if young and older adults performed the same task with the same memory load, that the benefit would be similar for both groups, though older adults would likely show an overall age-related deficit. We have previously shown that, when performing the same task, other encoding manipulations that improve source memory (such as self-referential processing) have similar benefits for young and old when performing the same task, though age-related deficits remain (Dulas, et al., 2011).

Another possibility is that, while encoding support may benefit older adults, it is not sufficient to boost source memory accuracy to the level of the young. Previous work in associative memory has shown that only when older adults are given support at both encoding and retrieval do they perform similarly to young adults (Naveh-Benjamin, et al., 2007). This corresponds with other data suggesting that age-related memory deficits may not be solely confined to encoding impairments, but also alterations in strategic retrieval (Luo & Craik, 2009), monitoring (Gallo, Bell, Beier, & Schacter, 2006), and declines in executive processes related to source memory retrieval (Hasher & Zacks, 1979; M.K. Johnson, et al., 1993). Thus the present behavioral results may be further evidence that, despite the benefit of encoding support, older adults still have deficits in associative memory and recollection, possibly related to retrieval deficits.

4.2: ERP Results

As predicted based on previous research (Kuo & Van Petten, 2006), explicit direction of attention at encoding to the conjunction of item and feature not only improved source memory accuracy, but attenuated late frontal-positivity effects, often attributed to post-retrieval monitoring. Additionally, the encoding manipulation did not appear to modulate early parietal old/new effects, typically associated with retrieval from the medial temporal lobe. This reinforces the suggestion that support at encoding may alleviate the need for strategic retrieval processing. Thus, by binding together an item and feature during encoding, the recollection of that episode may be more vivid and require little or no monitoring before making a response. Given previous evidence that the PFC plays a role in executive processes involved in source memory retrieval (Dobbins, Foley, Schacter, & Wagner, 2002; M. K. Johnson, Kounios, & Nolde, 1997; Raye, Johnson, Mitchell K.J., Nolde, & D'Esposito, 2000; M. D. Rugg, Fletcher, Chua, & Dolan, 1999), it would appear that successful recollection of an item and its feature does not necessarily depend upon the PFC when encoded strongly enough (Kuo & Van Petten, 2006).

However, this account would go against suggestions these frontal ERP effects may be related to confidence (Cruse & Wilding, 2009). One would think that better integration at encoding would lead to greater confidence in a response at retrieval, and thus an augmented late-positivity ERP. Our results show the opposite, that the possibly “most confident” condition has an attenuated old-new effect. This may suggest that the neural correlates and processes underlying this late frontal effect may be varied in nature. Our results from the young adults in the Non-Explicit encoding condition may speak to this. The present results showed that young adults not only showed post-retrieval effects in the Non-Explicit condition, but that there were two distinct effects the differed in laterality, being left-lateralized from 800-1100ms, and right lateralized from 1100-1400ms. It is possible that there are multiple components within post-retrieval monitoring, though what these mechanisms are is still unclear. It has also been suggested that this effect may be modified by the number of internal decisions being made (Dobbins & Han, 2006), however this seems to be an unlikely explanation for the current results, as all trials at retrieval have the same number of questions.

With regard to older adults, the ERP results were consistent with a myriad of evidence showing attenuated late-frontal ERPs with aging (Gutchess, et al., 2007; Trott, et al., 1997; Wegesin, et al., 2002), despite matching for performance on the Non-Explicit condition, which showed late frontal post-retrieval monitoring effects in young adults. This stands in contrast to evidence suggesting that, when performance is matched, older adults ERPs show similar late frontal effects to young adults (Li, et al., 2004). However, while there was no evidence of post-retrieval monitoring in the older adults for either condition, encoding support significantly improved source memory accuracy, though less so than that for young adults. Given the lack of late-frontal effects and the differences in the magnitude of performance improvement, it is likely that other mechanisms must be underlying the age-related source memory deficits. Additionally, it is unlikely that older adults may simply have a delayed monitoring effect that came after our chosen time windows, as responses were made on average within less than 200ms of our 1400ms cutoff. It is possible that despite encoding support, there may still be a persisting encoding or binding deficit which could be apparent in the encoding ERPs.

As also predicted, our results suggest that explicit encoding support may alleviate age-related declines in the processing speed (Salthouse, 2000) of the early ERP effects in older adults. The old-new effects in the young had come online for both conditions within the 200-500 ms time window, as had the effects for the old under explicit direction of attention. However, older adults showed no reliable effects for the non-explicit condition. In improving performance, older adults were also beginning to look more like the young in terms of ERPs (Li, et al., 2004). While the main interest of the present study was the late frontal ERPs, the current results may suggest that explicit encoding instruction may help attenuate age-related slowing and speed of retrieval/recognition of strongly bound associates.

Unfortunately, the present study did not allow for an investigation of source effects (i.e. Source Correct vs. Source Incorrect) due to low numbers of trials in the latter condition. Thus it is unclear exactly the role such an encoding manipulation is playing on recollection. Given that the paradigm employed objects and colors, i.e. an object feature, it is possible that the boost in performance seen in young and older adults is related to unitization of item and feature (Diana, Yonelinas, & Ranganath, 2008). Unitization would suggest that contextual memory is being supported by familiarity based processing. Given that the results showed no alterations in post-retrieval monitoring, or early parietal old-new effects, it is possible that unitization is the mechanism behind the memory enhancement. The stronger frontal effects seen for the Explicit condition in older adults during the 200-500 ms time window may be related to a stronger FN400. It has been suggested that the FN400 is related to familiarity (Curran, 2000), thus it is possible that the explicit condition is boosting the familiarity of the item, which may support object feature binding, such as item and color. This would also fit with the assertion that the contribution of familiarity to source recognition may depend on how the item is initially processed (Diana, et al., 2008), which is exactly what is manipulated in the current study. Given that familiarity may be spared with age (Davidson & Glisky, 2002; Parkin & Walter, 1992), this could act as a means of improving source memory accuracy via spared familiarity. Further research using different items and contexts that are not easily unitized could help address this question.

CHAPTER 5

CONCLUSIONS

In summary, the current study demonstrated that explicit encoding instruction which directs attention toward item and source can boost source memory accuracy in both young and older adults, though this benefit may not be as large for older adults. Older adults failed to match the young in source memory accuracy under the supported condition, even with a lesser memory load, suggesting additional age-related impairments not attenuated by encoding instruction. While explicit direction at encoding may attenuate frontally-mediated monitoring effects, it is unclear still exactly what is making up those effects, as young adults showed two spatially and temporally distinct post-retrieval monitoring effects. Additionally, it is possible that the encoding support taps into spared familiarity processes in older adults, perhaps through unitization. Given the modulated FN400, in the absence of differences between parietal old-new effects and absence of late frontal effects, this may be a likely mechanism for boosting source memory in older adults. Future research should employ additional imaging techniques such as fMRI to determine the neural correlates of the alterations caused by encoding support. Research teasing apart the mechanisms underlying the late frontal ERP effects is also necessary to better understand older adults' deficits and the means for attenuating them.

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